

### **REMARKS**

As of the filing of the present Office Action, claims 1-24 and 38-40 were pending in the above-identified US Patent Application.

In the Office Action, the Examiner withdrew all previous rejections of the claims, but then rejected all of the pending claims on new grounds under 35 USC §103. In response, Applicants have amended the claims as set forth above. More particularly:

Independent claim 1 has been amended to incorporate the limitations of its dependent claim 38.

Independent claim 8 has been amended to incorporate the limitations of its dependent claim 12 (now canceled without prejudice).

Dependent claim 2 has been amended to recite limitations that find support in Applicants' specification at paragraphs find support in Applicants' specification at paragraphs [0073] and [0074].

Dependent claim 16 has been amended to correctly identify the "liberating means," and to recite that the liberating means (14,16,18,182,184,186) liberates the chemisorbed hydrogen atoms from the dangling bond sites by passing photonic energy through said porous mesh (which finds support at paragraph [0058]), or passing electrical current through

said porous mesh (which finds support at paragraph [0039]), or creating an electrical field across said porous mesh (which finds support at paragraph [0057]).

In view of its limitations being incorporated into parent claim 1, claim 38 has been amended to recite the releasing means (14,16,18,182,184,186) in the same manner as the liberating means of claim 16.

New dependent claim 41 depends from independent claim 1 and recites a limitation that find support in Applicants' specification at paragraph [0071].

New dependent claim 42 depends from independent claim 1 and recites a limitation that find support in Applicants' specification at paragraph [0053].

New dependent claim 43 depends from independent claim 1 and recites a limitation that find support in Applicants' specification at paragraphs [0046] to [0047].

New dependent claims 44 and 47 depend from independent claims 1 and 8, respectively, and recite a limitation that find support in Applicants' specification at paragraph [0058].

New dependent claims 45 and 48 depend from independent claims 1

and 8, respectively, and recite a limitation that find support in Applicants' specification at paragraph [0039].

New dependent claims 46 and 49 depend from independent claims 1 and 8, respectively, and recite a limitation that find support in Applicants' specification at paragraph [0057].

Applicants believe that the above amendments do not present new matter, and that the amendments to the independent claims strictly comply with 37 CFR §1.116(a) as being limited to incorporating subject matter of their respective dependent claims, and thereby require only a cursory review by the Examiner. MPEP §714.13.

Favorable reconsideration and allowance of claims 1-11, 13-24, and 38-49 are respectfully requested in view of the above amendments and the following remarks.

**Rejections under 35 USC §112, second paragraph**

As noted above, dependent claim 16 has been amended to correctly use the term "liberating means" consistent with its parent claim 8, instead of "releasing means." Therefore, this rejection is believed to be overcome, and Applicants respectfully request its withdrawal.

### **§103 Rejections of Independent Claim 1 and Its Dependent Claims**

Independent claim 1 and its dependent claims 2-6, 19-24 and 39 were rejected as unpatentable over U.S. Published Patent Application No. 2004/0016769 to Redmond in view of U.S. Patent No. 4,265,720 to Winstel and U.S. Pat. No. 5,882,496 to Northrup et al. (Northrup) and as evidenced by U.S. Patent No. 5,926,711 to Woo et al. (Woo), claim 7 (which depends from claim 1) was rejected as unpatentable over Redmond, Winstel, Northrup and Woo in further view of U.S. Patent No. 5,196,377 to Wagner, and claims 17, 18 and 38 (which depend from claim 1) were rejected as unpatentable over Redmond, Winstel, Northrup and Woo in further view of U.S. Published Patent Application No. 2003/0170939 to Yamazaki et al. (Yamazaki).

In view of the incorporation of the limitations of claim 38 into independent claim 1, the rejection based solely on the combination of Redmond, Winstel, Northrup and Woo is believed to be overcome, and the remaining rejections of independent claim 1 and its dependent claims will be treated as further requiring the teachings of Yamazaki, applied in the rejection of claim 38.

Applicants respectfully request reconsideration of the rejections of independent claim 1 and its dependent claims in view of the amendments

presented above as well as the following comments.

As now amended, independent claim 1 requires the limitation from its dependent claim 38 that the releasing means causing the chemisorbed hydrogen atoms to be liberated from dangling bond sites is a light source, a current source, a voltage source, or a combination thereof. In setting forth the rejection of independent claim 1, the Examiner cited Redmond for disclosing "a heating system for releasing hydrogen from the hydrogen storing material," and stated:

Examiner's note: According to the specification of the present application, "The silicon activation energies, i.e., the adsorption and desorption energies of hydrogen on silicon, must also be controlled. This is accomplished through one or more techniques comprising . . . temperature activation . . .". In other words, by controlling the temperature of the hydrogen storing material, the silicon activation energy is also inherently controlled. Therefore, the control system and heating system taught by Redmond implicitly controls the activation energy of hydrogen by controlling the temperature of the hydrogen storing material. In addition, the heating system is an equivalent structure for causing the chemisorbed hydrogen atoms to be liberated from the dangling bond sites to be released as hydrogen gas from the housing through the at least one passage.

Office Action, paragraph bridging pages 3 and 4.

In setting forth the rejection of dependent claim 38, whose limitations are now

recited in claim 1, the Examiner explained

Redmond as modified by Winstel and Northrup et al does not expressly teach a releasing means that comprises a light emitting diode; or a releasing means that comprises a light source that emits photon energy at a wavelength of about 660 nanometers and the photon energy through the porous silicon and onto the interior surfaces of the porous silicon to liberate the chemisorbed hydrogen atoms from the dangling bond sites on the interior surfaces. The Yamazaki reference teaching the concept of forming crystalline silicon by sputtering a single crystalline silicon target in a mixture of hydrogen and argon, wherein the silicon atoms are coupled with hydrogen atoms at their external surfaces in order to terminate their dangling bonds, and wherein the Si-H bonds reacts with other Si-H bonds to convert to Si-Si bonds by radiation of a beam emitted from a light source (See paragraph [0049]). In other words, hydrogen atoms are liberated from the silicon material by a releasing means that comprises a light source that emits photon energy. In addition, it is well known in the art that light sources such as light-emitting diodes are commonly used. Further, one skilled in the art would know that a light source that emits photon energy at a wavelength of about 660 nanometers would be necessary to liberate chemisorbed hydrogen atoms from a silicon material.

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to substitute the Redmond/Winstel/Northrup method of releasing hydrogen with a releasing means that is a light source, wherein the releasing means comprises a light emitting diode because the substitution of one known method for another would have yielded predictable results to one of ordinary skill in the art at the time of the invention.

Office Action, paragraphs bridging pages 14 and 15.

Applicants respectfully disagree. Yamazaki describes a process for creating solid films of silicon from clusters deposited on a substrate and having Si-H dangling bonds. Yamazaki uses the heat - not the photonic energy - of a laser or halogen lamps ([0049]) to perform a heat treatment at 450°C to 700°C, which destroys the matrix of porous silicon. Experimentation conducted at the University of Alberta in 2006 under EMTEC grant EFC-H2-3-1C, ("Thermodynamic Analysis of a Novel Hydrogen Storage Material: Nanoporous Silicon", P.J. Schubert and A.D. Wilks, Am. Ceramics Soc. Hydrogen '08 Conference, Cocoa Beach, FL) shows that heating silicon to about 420°C causes silicon bonds to reform, thereby destroying their ability to store hydrogen. For this reason, the teachings of Yamazaki are completely contrary to Applicants' teachings, because Yamazaki only uses a light source to heat silicon, remove hydrogen, and form Si-Si bonds, which destroys the ability of the silicon to store hydrogen.

Furthermore, because Yamazaki only proposes the use of light to heat silicon, one would not be motivated by Yamazaki to use light at a wavelength of 660 nanometers since heat, e.g., ultraviolet radiation at about 10 to 380 nm wavelengths, would be of importance to Yamazaki. Finally, Yamazaki neither teaches nor suggests the dual effect of Applicants' 660 nm

wavelength, which in addition to being able to pass through silicon, is able to excite Si-H bonds without causing Si-Si bonds to form. Yamazaki is only interested in surface Si-H bonds for the purpose of agglomerating adjacent clusters, and therefore has no need for a wavelength that will pass through silicon.

In effect, Yamazaki merely discloses what the Examiner had already noted regarding Redmond in reliance on Applicants' teachings: "The silicon activation energies, i.e., the adsorption and desorption energies of hydrogen on silicon, must also be controlled. This is accomplished through one or more techniques comprising . . . temperature activation . . . ." However, Applicants are not claiming the use of temperature or heat to control the adsorption and desorption energies of hydrogen at the exterior surface of silicon, but instead are using a light source (and/or current source and/or voltage source) to control the adsorption and desorption energies of hydrogen at interior surfaces of porous silicon.

Finally, Applicants note that the Examiner's conclusion that Redmond's "heating system is an equivalent structure" is based entirely on Applicants' disclosure, an improper basis for the rejection because "[t]he teaching or suggestion to make the claimed combination and the reasonable



expectation of success must both be found in the prior art, not in applicant's disclosure." *In re Vaeck*, 947 F.2d 488, 20 USPQ2d 1438 (Fed. Cir. 1991).

Applicants therefore respectfully request withdrawal of the §103 rejection of independent claim 1 and its dependent claims.

Applicants also believe that the prior art fails to disclose or suggest:

- The enhancement of hydrogen adsorption by features (dendritic spikes or non-conformal growth) formed by an additive silicon deposition process, as recited in amended claim 2.
- A releasing means that liberates chemisorbed hydrogen atoms from dangling bond sites in porous silicon by passing photonic energy through the porous silicon, or passing electrical current through the porous silicon, or creating an electrical field across the porous silicon, as recited in amended claim 38 and as individually recited in new claims 44, 45 and 46. Instead, the prior art relies on extraneous equipment placed around the silicon or other material on which hydrogen is adsorbed, and does not use silicon itself as part of the circuit/medium used to liberate the hydrogen atoms.
- Feature sizes of about one nanometer, as recited in new claim 41.
- Etched pits in addition to existing porosity in a mass of porous silicon, as recited in new claim 42.

- Releasing means actually disposed on a mass of porous silicon, as recited in new claim 43.

### **§103 Rejections of Independent Claim 8 and Its Dependent Claims**

Independent claim 8 was rejected as unpatentable over Winstel in view of U.S. Patent No. 7,135,057 to Kornilovich, in further view of Northrup and as evidenced by Woo, claims 9-11 (which depend from claim 8) were rejected as unpatentable over Winstel, Kornilovich, Northrup and Woo in further view of U.S. Published Patent Application No. 2002/0158284 to Kim, claims 12 and 13 (which depend from claim 8) were rejected as unpatentable over Winstel, Kornilovich, Northrup and Woo in further view of U.S. Published Patent Application No. 2002/0172820 to Majumdar et al. (Majumdar), claim 14 (which depends from claim 8) was rejected as unpatentable over Winstel, Kornilovich, and Northrup in further view of U.S. Patent No. 4,594,229 to Ciszek et al. (Ciszek) and U.S. Patent No. 6,040,230 to Anthony et al. (Anthony), claims 15 and 40 (which depend from claim 8) were rejected as unpatentable over Winstel, Kornilovich and Northrup in further view of Redmond, and claim 16 (which depends from claim 8) was rejected as unpatentable over Winstel, Kornilovich, Northrup and Redmond in further view

of Yamazaki.

In view of the incorporation of the limitations of claim 12 into independent claim 8, the rejection based solely on the combination of Winstel, Kornilovich, Northrup and Woo is believed to be overcome, and the remaining rejections of independent claim 8 and its dependent claims will be treated as further requiring the teachings of Majumdar, applied in the rejection of claim 12.

Applicants respectfully request reconsideration of the rejections of independent claim 8 and its dependent claims in view of the amendments presented above as well as the following comments.

As now amended, independent claim 8 requires the limitation from its dependent claim 12 that the silicon columns have diameters of about one nanometer. In setting forth the rejection of dependent claim 12, the Examiner explained

Winstel as modified by Kornilovich and Northrup does not expressly teach silicon columns that have diameters of about 1 nm. The Majumdar reference discloses methods of forming nanowire structures with a diameter of approximately 5 nm to approximately 50 nm (See paragraph [0068]).

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the Winstel/Kornilovich/Northrup system for

storing and retrieving hydrogen to include silicon columns that have diameters of about 1 nm in order to improve the storage efficiency of the gas storage medium by increasing the surface area of the silicon columns. In addition, even if the range of the prior art and claimed range do not overlap, obviousness may still exist if the ranges are close enough that one would not expect a difference in properties (In re Woodruff 16 USPQ 2d 1934 (Fed. Cir. 1990)). (Emphasis added).

Office Action at page 11.

Applicants respectfully disagree. First, reducing the diameter of a silicon column clearly does not increase surface area, but in fact reduces surface area. Therefore, Applicants smaller silicon columns is contrary to the teachings of Kornilovich, regardless of the teachings of Majumdar. Second, as acknowledged by Majumdar, a consequence of this difference in size range is that quantum effects are evident in structures with feature sizes of this order, which is on the same order as the size of an atom. Therefore, Applicants respectfully believe that the Examiner is incorrect to assume that “one would not expect a difference in properties” by reducing Kornilovich’s silicon columns on the basis of Majumdar.

Applicants therefore respectfully request withdrawal of the §103 rejection of independent claim 8 and its dependent claims.

Applicants also believe that the prior art fails to disclose or suggest a

releasing means that liberates chemisorbed hydrogen atoms from dangling bond sites in porous silicon by passing photonic energy through the porous silicon, or passing electrical current through the porous silicon, or creating an electrical field across the porous silicon, as recited in amended claim 16 and as individually recited in new claims 47, 48 and 49. Instead, the prior art relies on extraneous equipment placed around the silicon or other material on which hydrogen is adsorbed, and does not use silicon itself as part of the circuit/medium used to liberate the hydrogen atoms.

**Closing**

In view of the above, Applicants believe that the claims define patentable novelty over all the references, alone or in combination, of record. It is therefore respectfully requested that this patent application be given favorable reconsideration.

Should the Examiner have any questions with respect to any matter now of record, Applicants' representative may be reached at (219) 462-4999.

Respectfully submitted,



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June 1, 2009  
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